and not so much open to the objection of violating long established principles. But if I have insisted particularly on the theory of Lorentz, it was just for the purpose of bringing out as clearly and forcibly as possible the differences between the old and the new.

Besides, there is one minor feature in the form of presentation adopted by Lorentz and Abraham which appeals to me as worthy of attention: it is the consistent use of the vector analysis of Gibbs and Heaviside. And perhaps this is really somewhat more than a mere matter of form. Burkhardt[12] has shown that this vector analysis has a rational mathematical basis. And after the numerous and manifold applications that have been made of this method its usefulness can no longer be questioned. The diversity of notations used by different authors can hardly be regarded as a serious objection. Have we not a large variety of notations even in so old and well-established a branch of mathematics as the differential calculus? The important thing about vector analysis is that it teaches to think in vectors and fields. E. Picard,[13] in a lecture, has recently called attention to the importance of the field even in ordinary elementary mechanics. A. Föppl has led the way in using vector symbols in an elementary treatise on technical mechanics.

Vector addition is now more or less familiar even to the student of the most elementary mechanics, largely owing to the influence of graphical statics. Is it not time to introduce at least the scalar and vector products and the time-differentiation of vectors in the mechanics of the particle and the rigid body? The gain in clearness and conciseness in stating the more general propositions is certainly great. In the mechanics of deformable bodies and media (hydrodynamics, elasticity), the general theory of vector fields, with the fundamental notions of divergence and curl, flux and flow, lamellar and solenoidal fields, etc., should surely form the preliminary mathematical basis for all further study; and here the simple symbolism of vector analysis is particularly well adapted to the subject.

But whatever may be the form of presentation selected, the study of the fields of scalars, vectors and higher point functions, so intimately connected with the modern views of physical phenomena, might well claim more attention on the part of the pure mathematician than it has so far received.

ALEXANDER ZIWET.

[12] *Mathematische Annalen*, Vol. 43 (1893), pp. 197–215.

[13] 'Quelques réflexions sur la mécanique, suivies d'une première leçon de dynamique,' Paris, 1902.

THE SANITARY VALUE OF A WATER ANALYSIS.[1]

TWENTY years ago, the vice-president of this section, the late Professor William Ripley Nichols, took as the subject of his address, 'Chemistry in the Service of Public Health,' saying: "If any are inclined to criticize my choice of that branch of applied chemistry with which I am most familiar, I trust they will consider that, after all, few of us have the opportunity, or, let us confess it, the ability to carry research and speculation to the height to which chemistry is capable of rising." Agreeing fully in the sentiment of this last sentence, though not at all as applying to Professor Nichols, whose marked ability as an investigator was recognized by all, I feel that I can best fulfill the clause in our constitution which requires the several vice-presidents to give an address before their

[1] Address of the vice-president and chairman of Section C, Chemistry, American Association for the Advancement of Science, New Orleans, December, 1905.

respective sections, by taking for my address a subject that does not call for the speculative thought of theoretical chemistry, but rather the careful consideration of some one subject in my own field of work. I have, therefore, chosen as my topic 'The Sanitary Value of a Water Analysis.'

A question of great importance to a community is the character of its water supply, and of equal importance to the individual is the purity of the water that is used in his household, whether it comes from a city main, or an isolated well in the country. That this was not always so considered hardly requires mention, for it is not a great many years since disease was considered a direct visitation of providence. The first investigation that attracted public attention to the fact that there might be a connection between the use of polluted water and disease may be said to be what is known in sanitary science as the 'Broad Street Well Investigation.' In the epidemic of cholera in London in 1854, the parish of St. James, Westminster, which in previous epidemics had suffered, on the whole, less than many other parts of London, suffered most severely, the death rate reaching two hundred in ten thousand. The whole parish was not equally affected, and the center of infection, or the special cholera area was in the neighborhood of Broad Street, and attention was drawn to the fact that, though city water was supplied to this district, a well situated on Broad Street was used to a very large extent for household purposes. An investigation followed and it was shown that of the deaths that occurred during the first week of the outbreak among persons living in this neighborhood, 82 per cent. were known to have used the water from this well, and that houses and factories in the same radius where the water from this well was not used seemed to be exempt from the disease.

A strong case between cause and effect was thus made out, and when a subsequent examination showed that there was direct leakage from an open privy into this well, it established as clearly as could be done by circumstantial evidence that the epidemic in St. James parish in 1854 was caused by polluted water.

A further striking proof that sewage polluted water may become the effective vehicle of the actual poison of disease was furnished through the cholera epidemic in London in 1866, but the theory that water is one of the most dangerous carriers of infection of cholera and of typhoid fever may be said to date from 1872, and to have been the result of the careful investigation of the typhoid fever epidemic in that year in Lausen, Switzerland. To-day we recognize as one of the best established theories of sanitary science that both cholera and typhoid fever are water-borne diseases, and that the primary cause of the large death rate from typhoid fever is due to the use of polluted waters.

The late Professor Thomas M. Drown divided all waters into two classes, namely, normal and polluted waters, and stated, as regards normal waters, that although they differ very widely in character from the pure colorless mountain brook to the dark-colored water from swampy ground, they are all characterized by never having received any contamination connected with man, and although often far from pure waters, differ from a polluted water in one most important respect, in that they are not capable of producing, as far as known, any specific germ disease.

It is true that many normal waters, on account of the large amount of vegetable matter they contain, are unfit for household use, although they may be sanitarily safe waters in the sense of not being the

vehicle of the germs of disease. Hence the sanitary value of a water analysis depends not on determining the amount of organic matter which a water contains, but on the amount of information it can give in answer to the question, 'Is a given water a normal or a polluted water?' or, stated in other words, 'How far can analysis determine whether or not the organic matter in a water is of vegetable or animal origin?'

In order to answer this question it is necessary to divide natural waters into three classes: Surface, subsoil or ground, and artesian waters. These waters differ so radically in character from each other that, although the data from which deductions can be drawn as regards pollution are practically the same, yet the correct interpretation of these data depends upon the knowledge as to which group the water in question belongs, and a clearer idea of the subject under discussion can be obtained if we first consider surface waters and apply the results of this study to ground and artesian waters.

It is often claimed that there is no value in a sanitary analysis of a surface water, that an inspection of the watershed may give all, and often much more, information than can be obtained from the analysis of the water. If sewage is seen to be entering a pond, an analysis is unnecessary to show that it is polluted. If the watershed is uninhabited, the water can not be polluted.

There is no question about the value of a survey and that a survey not only aids in drawing the proper deductions from the data of an analysis, but that often it is necessary for a correct explanation of the data. Still, there are many cases where, unless large interests are involved, a careful and complete survey is practically impossible on account of the expense, and where the chief reliance must be placed on the sanitary analysis. Further, a survey alone, though it may show pollution, does not tell the amount of pollution, nor show the changes that have taken place in the polluting substances. A survey alone can never give all the desired information, and a sanitary analysis, even of a surface water, must always have a value. It is from this point of view that what I have to say regarding surface waters must be considered.

Very early in the study of polluted waters attempts were made to devise methods for detecting certain definite organic compounds which were known to be formed by the decomposition of the nitrogenous products contained in sewage, but without success, and there is very little hope that much knowledge can be gained as to the nature of the organic matter through this line of investigation. The decomposition of the nitrogenous products contained in sewage takes place so rapidly that the isolation of any particular compound like crystin, or any group of compounds, like the amido group, can only be looked for when the pollution is very recent and in very large amounts.

Though it is apparently impossible to isolate from a water any particular nitrogenous organic compound known to occur in sewage, the amount of nitrogen and the amount of carbon contained in these compounds can be determined, and among the first, if not the first, to attempt to determine from the amount of nitrogen and carbon in a water whether the organic matter was of animal or vegetable origin was the late Sir Edward Frankland. On examining the residue left on evaporation of water from peat bogs he found the ratio of nitrogen to the carbon was as 1 to 12, while in the residue from fresh sewage it was as 1 to 2.1, and in the residue from polluted waters, as water containing leakage from cesspools as 1 to 3.1. From these and similar observations he concluded that in surface waters the ratio of the organic nitrogen to the organic carbon in the residue

left on evaporation of such waters afforded trustworthy evidence as to the source of the organic matter. Thus he concluded, that if the ratio was as low as 1 to 3 the organic matter was of animal origin; if as high as 1 to 8 it was chiefly, if not exclusively, of vegetable origin, and that if the ratio was between these two proportions the analyst must be guided in his opinion by the amount of inorganic nitrogen the water contained, and by his knowledge of the surroundings of the source of the water.

This work of Frankland deserves much closer study than it has as yet received. His idea that reliable information regarding the source of the organic matter in a water can be obtained from a knowledge of the amount of organic carbon and organic nitrogen is, in my opinion, undoubtedly sound. The reason why this method has not been more generally adopted is undoubtedly due to the difficulties in correctly determining these two factors by the process used by Frankland, which consisted in measuring the amount of carbon dioxide formed and the amount of nitrogen given off, by the combustion of the residue left on evaporation. If as simple a process for determining the organic carbon as we now have for determining the organic nitrogen could be devised, I believe Frankland's method for deciding upon the character of a surface water would receive the careful study it certainly deserves.

The method of determining the character of a water from the ratio that exists between the carbon and nitrogen, being recognized as of comparatively little practical worth, on account of the difficulty of determining the carbon, attention to-day is concentrated upon the nitrogen content of a water.

The usual method used for determining the nitrogen in the undecomposed nitrogenous compounds is the albuminoid ammonia method of Wanklyn. It gives only an approximation of the total amount of nitrogen thus occurring, but taken in connection with the free ammonia present it undoubtedly often gives valuable indications as to the source of the nitrogenous compounds.

In fresh sewage the amount of nitrogen as free ammonia is from three to four times that of the nitrogen in the albuminoid ammonia, and in sewage effluents from twenty to thirty times, while in peaty water or water containing an infusion of leaves the nitrogen in the albuminoid ammonia is from ten to twenty times the nitrogen in free ammonia, hence when a surface water, not including rain or snow water, gives a greater amount of nitrogen as free ammonia than it does as albuminoid ammonia the indications are that the water has certainly been polluted by sewage and that the source of the organic matter is of animal origin, and with a large amount of nitrogen as albuminoid ammonia (over twenty-five hundredths of a milligram per liter), a ratio of the nitrogen of the free ammonia to the nitrogen of the albuminoid ammonia of less than 1 to 5 is suspicious.

Free ammonia contained in a water may be rapidly removed by plant life or be changed into nitrites and nitrates, and then be absorbed by algal forms, the plant life thus stimulated again adding to the water undecomposed nitrogenous compounds. Consequently, while a low ratio as 1 to 5 between the nitrogen of the free ammonia and the nitrogen of the albuminoid ammonia indicates pollution, the reverse can not be said to be a strong indication that the water is a normal water, one containing only vegetable matter.

It is a well-established fact that it is not safe to form a judgment of a water from the consideration of any single nitrogen factor, and that unpolluted surface waters are known where the nitrogen, as albuminoid ammonia, is much larger than in

certain waters known to be polluted, and the same can also be said of nitrogen as free ammonia and the nitrogen as nitrites and nitrates, and yet something can be learned from the consideration of each of these factors. Nitrogen as albuminoid ammonia in a water analysis, as has been said, represents the nitrogenous matter which has not undergone decomposition, and it is found that in unpolluted waters this amount varies greatly, some waters giving almost no nitrogen in the above form, others as much as one milligram per liter. If, however, the nitrogenous substances are of vegetable origin the water is usually highly colored, and consequently a colorless water, containing that amount of nitrogenous matter represented by 0.25 milligram of nitrogen as albuminoid ammonia per liter is looked upon with suspicion.[1]

Free ammonia always indicates organic matter in the process of decomposition. In unpolluted surface waters it is rarely high, being removed almost as fast as formed by vegetable and animal organisms in the water and an amount of nitrogen as free ammonia above 0.05 milligram per liter is unusual, and if it does occur the water can not be considered as an unpolluted water unless that fact is clearly established by other data.

In drawing conclusions, not only from the nitrogen as free ammonia, but also from the ratio that exists between the nitrogen as free ammonia and the nitrogen as albuminoid ammonia, what is known as the 'seasonal variation' must be considered. Namely, that the amount of nitrogen as free ammonia in northern surface waters is usually greater during the late autumn and early winter than at any other time. This is due to two facts: first, that in cold weather the free ammonia is not absorbed quickly by plant life, and second, that as cold weather begins the surface water of ponds and reservoirs, growing colder, sinks and the bottom water rises, bringing with it the decaying matter from the bottom, increasing the amount of free ammonia often to three times the average amount of the year. This also affects to a certain extent the nitrates, but not nearly to the same amount.

The nitrogen in the other two nitrogen factors of the nitrogen content occurs only in very small amounts. Nitrites in a water are due either to the oxidation of ammonia or to the reduction of nitrates, and being unstable quickly undergo change. Formerly, nitrogen as nitrites in amounts exceeding 0.002 milligram per liter were thought to be a strong indication of recent pollution, and though we now know that unpolluted swamp waters may contain over twice that amount, still more than 0.002 milligram is an unfavorable indication.

Nitrogen in the form of nitrates indi-

[1] It has lately been suggested that the determinations of organic nitrogen should be substituted for the determinations of nitrogen as albuminoid ammonia in water analyses. There is, of course, no question that nitrogen as albuminoid ammonia only gives the amount of nitrogen that is present in nitrogenous substances decomposed by an acid solution of potassium permanganate, and not the total organic nitrogen. With waters, however, unless greatly polluted, the amount thus obtained equals approximately one half of the organic nitrogen, so that the organic nitrogen, if desired, can be calculated sufficiently closely from the nitrogen of the albuminoid ammonia. In sewage work, however, the case is very different. There is no fixed ratio between the organic nitrogen and nitrogen as albuminoid ammonia, and in determining the strength of a sewage, and in determining the amount of purification that takes place in various processes of treatment, the organic nitrogen is a most important factor and should be determined. The nitrogen as albuminoid ammonia, on the other hand, is of little value, changing as the sewage ages, on account of nitrogenous substances not acted upon by an acid solution of potassium permanganate breaking down, giving nitrogen compounds more easily decomposed. The amount of nitrogen as albuminoid ammonia, as a rule, increases as the sewage ages.

cates the amount of nitrogenous matter that has undergone complete decomposition. It is rarely absent from a normal water. It is never present in any large amount, seldom exceeding one tenth of a milligram per liter. Higher amounts than this, being unusual, must be looked upon with suspicion.

The interpretations I have just made apply chiefly to reservoir, pond and lake waters. River waters differ from pond, lake or reservoir waters in the essential particular that the former are in rapid motion and the so-called nitrogen cycle may take place many times during the course of their flow. High nitrogen as free ammonia, as albuminoid ammonia and as nitrites, characteristic of recent pollution in ponds and reservoirs, may, in rivers, be due to the decomposition of the algæ life, which was stimulated by the entrance of sewage in the upper stretches of the river, and the proper deductions to be drawn from these nitrogen data necessitate a knowledge of the river.

Though much valuable information can be obtained, as I have tried to show, from the careful study of the nitrogen content of a water, the water analyst does not depend alone upon these factors in forming an opinion as to the source of the organic matter, and turns to other chemical as well as to bacterial data to substantiate or modify the opinion thus formed. From the chemical point of view the most important of these data is the combined chlorine that a water contains. This is due to the fact that though chloride of sodium occurs in rain water, especially near the sea, and in small amounts is found in all soils, it is a characteristic constituent of sewage, the animal body expelling the same amount of salt as it absorbs.

A careful study of the amount of combined chlorine in normal waters made by Professor Thomas M. Drown, showed that in Massachusetts, where salt-bearing strata do not occur, the amount of chlorine in a surface water depended on its distance from the sea, and that for Massachusetts it was possible to establish normal chlorine, or, as they are commonly called, iso chlor lines.

The work begun by Professor Drown has been carried on by other investigators, and to-day the iso chlor lines for all the New England States and New York and New Jersey have been determined. The result of this work is that the amount of chlorine occurring in the surface waters of the above-named states gives most valuable information. Chlorine above the normal of the region shows pollution. It does not indicate whether the pollution is direct or indirect, but does show that sewage, from which the organic matter and the germs of disease may or may not have been removed by filtration through soil, has had access to the water. Chlorine above the normal is, therefore, always a suspicious sign which must be investigated. I know that it is claimed that in many of the western states, owing to geological conditions, very little information can be obtained from the determination of chlorine. I believe, however, more careful and thorough work is necessary to prove that such is the case, and that further investigation may show that though it is impossible to construct iso chlor lines running through the state, the normal chlorine of different localities in a state can often be determined.

Another factor that is often used in the attempt to decide whether or not a water contains an excessive amount of organic matter is the oxygen consumed. The oxygen consumed is not, however, a measure of the organic matter in a water, but only a measure of the amount of mineral reducing salts plus a certain amount of the organic matter, the amount depending on the method of determination used. It

gives, in my opinion, very little information as to the character of the organic matter, and is only valuable when different surface waters are to be compared with each other, or when used in filtration experiments.

The same may be said as regards color, turbidity and the amount of mineral matter that a surface water contains, that, though of essential importance in deciding on the value of a normal water as a potable water, they give little information as to pollution,

In the early days of bacteriology it was claimed that the final criterion as to pollution of a water would be furnished by aid of that science, and though this hope has not been fulfilled, the information that can be gained by a bacterial analysis is often of the highest importance. It not only aids in the interpretation of the chemical data, but may of itself show, almost without question, that a given water is polluted, for though attempts to isolate special pathogenic germs have generally failed, even in waters known to contain these forms, characteristic sewage forms, like the colon bacillus, can be isolated if they occur in any number in a water. Occurrence of numerous characteristic sewage bacteria can point only to one thing, pollution, and if such forms are found there is no question that the water receives sewage drainage. Bacteriology, however, can not determine, except very roughly, the amount of pollution, or the present condition of the polluting matter, nor does it give but very little, if any, information as to past pollution. If the pollution is recent and of any considerable amount, a careful bacterial examination will show the fact, and probably better and more convincingly than any chemical analysis. If the pollution is more remote, more information can, as a rule, be drawn from chemical than from bacterial data. If the polluting matter has filtered through the soil before entering the water, bacterial work will not indicate the fact.

As a general statement, it may be said that a bacterial analysis, while giving information as regards recent and continuous pollution, gives no information as to the past history of a water, and in this respect differs from a sanitary chemical analysis.

All natural waters contain bacteria, and even if the true colon bacillus does not occur in many normal surface waters, one closely akin to it can often be found if a sufficient amount of the water be taken for examination. The mere presence of bacteria or even the colon bacillus, if found only in large volumes, does not, therefore, signify pollution.

The number of bacteria found in a surface water depends not only upon the organic matter a water contains, but to a greater or less extent upon various natural causes, such, for instance, as the character of the soil of the watershed, the rainfall, the time of year the examination is made, and these considerations must be taken into account when attempting to determine the character of the water from the number of bacteria present. Arbitrary standards have been proposed from time to time, and of these Dr. Sternberg's, that a water containing 500 bacteria to the cubic centimeter is open to suspicion and one containing over 1,000 bacteria is presumably contaminated by sewage or surface drainage, is probably as satisfactory as any that could be devised. Though most artificially filtered waters and many reservoir waters contain not over 100 bacteria to a cubic centimeter, to state that a surface water showing on a single examination a much greater number than 500 per cubic centimeter was probably polluted, would be unjustifiable, and the significance of the data can only be determined when the average bacterial count of the water under examination is known, or when it is con-

sidered in connection with the chemical data.

A certain added amount of information may be gained as to the weight to be placed on the total bacterial content of a water, by also determining the number of colonies that develop on agar plates at blood temperature and the number that decompose lactose with the formation of acid. According to Rideal and also to Winslow, in an unpolluted water the proportion between the total number of colonies obtained on gelatine plates at 70° Fahrenheit and the number obtained on agar plates at 98 degrees Fahrenheit should not be greater than 12 to 1, and Winslow and Prescott state that in normal Massachusetts waters the total number of organisms growing at the body temperature rarely exceeds 50 per cubic centimeter, and that acid producers are generally absent.

The information that can be obtained by the examination of a water for the colon bacillus is much more positive and important than that which can be obtained from a bacterial count, for though undoubtedly the colon bacillus is not confined to the secretions from mammals, the intestines of the higher vertebrates form a better environment for its growth and multiplication than any other which occurs in nature, consequently drainage from domestic and agricultural wastes of human life must be considered as the method by which large numbers gain access to surface waters. It follows, therefore, that a water containing large numbers of colon bacilli must be looked upon as a polluted water, and the generally accepted statement of to-day is that if the colon bacilli occur in sufficient numbers in a surface water to be detected in the majority of one cubic centimeter samples tested (at least six samples being taken), it is almost positive indication of recent sewage pollution. Failure to detect colon bacilli when water is thus tested is not, however, a proof that the water is a normal water, though it is usually a proof that the pollution, if it exists, is not recent nor continuous.

Having attempted to give what I believe can be learned from the sanitary analysis of a surface water, ground and artesian waters remain to be considered, and with these waters the analyses assume far greater importance than with surface waters, for the area of the source of the water is often indefinite and rarely determinable with accuracy, and a careful and complete survey of what may be called the watershed is very difficult and generally impossible.

In determining the character of a ground water we make use of the same data that we have considered in speaking of surface waters, but the deductions drawn from the data are very different. This is due to the fact that the two waters differ so greatly in their chemical and biological characteristics that they can not be judged by the same standards.

Ground waters are surface waters which have percolated through the soil, and the changes which they have thus undergone are very similar to the changes which take place in the process known as slow sand filtration and it is from a study of this process that we are able to follow the changes that take place when surface waters pass into the soil.

In slow sand filtration of water we find that odor, color and turbidity are removed, that about 90 per cent. of the nitrogenous organic matter is oxidized, and that a part, varying from 50 to 75 per cent. of the nitrogen of the organic matter, is found in the filtrate as nitrates, that the amount of chlorine remains unchanged and that the bacteria are to a very large extent removed.

To apply the information thus obtained to ground waters it can be stated that an unpolluted ground water should be free

from color, odor and turbidity, that the amount of nitrogen as free and albuminoid ammonia should be very much less than in an unpolluted surface water, that the amount of nitrogen as nitrates should not exceed by more than 50 to 75 per cent. the nitrogen of nitrates of normal waters, and that the amount of chlorine should be the chlorine of the region, and bacterially the water should be very pure.

To go further, and from the filtration experiments and from the study that has been made during the past twenty years on ground waters, and express the statements of the last sentence in concrete numbers, it might be said that the best ground waters should certainly contain not over 0.01 milligram of nitrogen as free ammonia or over 0.02 milligram of nitrogen as albuminoid ammonia, no nitrogen as nitrites, not over 0.1 milligram of nitrogen as nitrates in a liter of water, and chlorine not above the normal of the region. When a water contains more than 0.05 milligram of nitrogen as free ammonia and 0.08 milligram of nitrogen as albuminoid ammonia, or 0.12 milligram of nitrogen as albuminoid ammonia, even if the free ammonia occurs in very small amounts, it is a sign of imperfect filtration or of subsequent pollution, and consequently such water should not be used for household purposes.

In making this statement, the fact that the nitrogen of organic matter in a soil can be oxidized by ferric oxide to ammonia has not been lost sight of. This is, however, not of common occurrence, and unless it can be proved in a given case to have taken place, the deductions that have been made must be considered as correct.

Nitrites in a ground water are a most unfavorable indication, though they are sometimes found in unpolluted well waters, due to the reduction of nitrates by iron, sand, or iron pipes through which the water is drawn from the well.

A ground water containing an amount of chlorine much in excess of the normal of the region and nitrogen as nitrates approaching 3 milligrams per liter, even with very small amounts of nitrogen as free and albuminoid ammonia, must be considered to have been originally polluted surface water, and on this account not a water free from possible danger.

Though, as has been stated, the number of bacteria in a ground water should be small, not over one hundred per cubic centimeter, numerous investigations of well waters giving no indication of pollution have shown that this number is often largely exceeded. This may be and is often due to the falling into a well of air and soil bacteria. The number of bacteria in well water, if not reaching into the thousands, can not, therefore, of itself be considered as an indication of pollution, though the cause of excessive numbers requires explanation.

A much better indication as to the pollution of ground waters is the ratio that exists between the number of bacteria developing at the temperature of 70° Fahrenheit and the number developing at blood heat, and the same conclusions as with surface water may be drawn from the ratio that is thus found.

The occurrence of acid forming bacteria indicates pollution, and the presence of colon bacillus in a ground water is almost positive proof that sewage drainage is present.

Artesian or underground waters are ground waters which have passed into or through underlying rock strata. The sanitary value of the analyses of such waters should be very great, for the pollution, if polluted, may be due not only to carelessness, which allows direct and continuous contamination from above, at the point where the water is tapped, but often to ground water which has not been purified

by filtration through soil having direct connection with the water in the well, owing to the seamy or faulty character of the rock or to the percolating water wearing channels through the rock, as often occurs in limestone formations. The source of pollution may, therefore, be many miles from the well, and through careful study of the geological formation, the dip of strata and general characteristics of the neighborhood should be made, the main reliance for deciding whether or not the water is a polluted one must often be the data obtained from the chemical and bacterial analyses.

Unfortunately, however, in the study of artesian water perplexing chemical and bacteriological results are often obtained. In artesian waters so situated that surface pollution seems impossible, amounts of nitrogen as free ammonia, as nitrites and as nitrates have often been found which, if occurring in ground waters, would cause them to be considered as polluted. The nitrogen of the nitrates in these waters may be due to fossil remains, and the nitrogen as nitrites and as free ammonia to the reduction of the nitrates by chemical action, as contact with iron sulphide, and the occurrence of the nitrogen as free ammonia also sometimes to some salt of ammonia existing in the strata through which the ground water passes. On this account the determination of the nitrogen content does not give as satisfactory data from which to draw conclusions as those obtained from the analysis of ground water.

The interpretations of the data obtained, however, always bearing the above facts in mind, are nearly the same as those stated when considering ground waters. An unpolluted artesian water should not contain any nitrogenous or carbonaceous organic matter and consequently the nitrogen as albuminoid ammonia should not be over 0.02 milligram per liter and the oxygen consumed, nitrites and mineral reducing substances being absent, should not exceed one tenth of a milligram.

The chlorine factor is of much less importance in the study of artesian waters than in the other two classes, for, as a rule, we have little or no knowledge of the normal chlorine of deep waters of any given region and consequently this datum has only the same value that it has in the analysis of surface waters in localities where the normal chlorine has not been determined.

Bacterially an artesian water should be a very pure water and at one time it was considered that an unpolluted artesian water was a sterile water. To-day, however, this is not the case. Examination of wells has shown that while in a few cases the water may be sterile, in the majority bacteria are present in varying numbers. These are, however, generally of slow-growing types and are not indicative of pollution. Should an artesian water, not in a region of thermal springs, show bacteria which develop in considerable numbers at the body temperature, the interpretation would be the same as in a ground water, that unpurified water or sewage was entering the well either from the immediate environment or through fissures and crevices in the lower strata. Acid-forming bacteria and the colon bacillus should never be found in artesian waters.

I am afraid I have already occupied by far too much of your time in giving my opinion as to the sanitary value of a water analysis and the information that can be derived from such an analysis, and in conclusion would only reiterate that to form a judgment as to the wholesomeness of a water the data of a sanitary water analysis, the source of the water, whether surface, ground or artesian, must be known; that a survey, even of a surface water, though

it may show whether or not the water is polluted, does not give information regarding the amount or condition of the polluting matter; that with ground and artesian waters it often gives very little information, and that an opinion regarding the character of such waters must, as a rule, depend on the sanitary analysis.

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SCIENTIFIC BOOKS.

Handbook of Metallurgy. (In two volumes.) By Dr. CARL SCHNABEL, Professor of Metallurgy at Berlin. Second edition. Volume I., Copper, Lead, Silver, Gold. Translated by HENRY LOUIS, Professor of Mining at Armstrong College, Newcastle-on-Tyne, England. 8vo, cloth covers, 715 illustrations. Pp. 1,123. Contains a geographical and a general index. New York and London, The Macmillan Company. Price, $6.50.

This volume, which is the English translation by Professor Louis of Dr. Schnabel's classic work, needs but the mention to declare its excellent merit, so widely known are both author and translator. The first German edition of Dr. Schnabel's admirable work of two volumes appeared in 1898, and was shortly afterward translated into English by Professor Louis. Both works were so well received that Dr. Schnabel issued a second edition, Vol. I. in 1902 and Vol. II. in 1904. The present book under review is Professor Louis' English translation of Vol. I. The English translation of Vol. II., which will also be made by Professor Louis, is expected to be published in 1906.

The translation of Dr. Schnabel's great work furnished the first complete treatise on metallurgy (except for iron) that has appeared in the English language, although many small text-books, covering the entire field but making no claim to thoroughness of detail, have been published; as have also several excellent monographs dedicated to the metallurgy of individual metals.

Dr. Schnabel's object has been to give a complete description of the metallurgical treatment of all the metals (except iron), pointing out the underlying chemical principles, and for each case, giving examples drawn from actual practise. His broad knowledge of the subject has rendered him eminently fitted for this herculean task, and he has supplemented his personal knowledge by full reference to and abstract from the works of that well-known trio of American metallurgical writers—Egleston, Peters and Hofman. So excellent was his work that the first edition received well-merited praise throughout the metallurgical world. A few adverse criticisms were made, but these were directed mainly to the mechanical features of the books—for instance, a collective index for both volumes was given at the end of volume II. and no index whatever in volume I. This objectionable feature of the first edition has been removed in the second edition, each volume of the latter having its individual indexes—an improvement of great value in referring to the books.

Another criticism of Dr. Schnabel's work was that too much space had been given to the history of active processes and the description of obsolete ones; but knowledge can not be too thorough for the earnest student or inventor who needs a reference work that will cover the entire subject. A knowledge of both past and present practise is needed in order to know not only 'what to do' but also 'what not to do.' The chemical principles which underlie a metallurgical process remain fixed and constant, but the application of new forces, the development of mechanical appliances for handling raw materials and part or wholly finished products (indeed, in many cases, for the physical action of the furnace itself) are important factors bearing on the proper conduct of metallurgical treatment of ore or metal. Frequently, metallurgical processes are of such rapid development that theory to-day becomes practise to-morrow; and, as a corollary to this fact, good practise to-day becomes merely historical record to-morrow. For this reason a comprehensive treatise on the subject should contain not only a description of present practise, but also a record of the developments which have led to it. In